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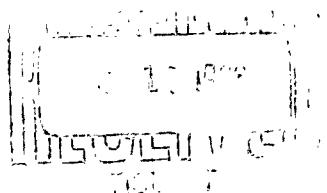
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BYRD STATION SNOW TUNNELS -  
WALL CLEARING STUDY

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U. S. NAVAL CIVIL ENGINEERING LABORATORY  
PORT HUENEME, CALIFORNIA

BYRD STATION SNOW TUNNELS -  
WALL CLEARING STUDY

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Final Report

by

C. W. Terry, Ph.D.

ABSTRACT

Present data on the closure rates in most of the tunnels at New Byrd Station, Antarctica indicates that trimming of the walls to maintain desirable clearances will not be required before Deep Freeze 65. A review of the Byrd Station drawings showed that about 75 percent of the tunnel wall surfaces will allow a relatively high degree of mechanization for economical wall trimming. Buildings and other obstructions will necessitate hand clearing in the remaining 25 percent. On a basis of tunnel clearing work at Camp Century, Greenland, tentative methods and equipment for trimming the walls and disposing of the waste snow were selected for Byrd Station. It was concluded that specific rates of closure and maximum allowable safe closures for the Byrd tunnels should be established at an early date. Also, precise techniques and equipment should be determined for each different tunnel situation during Deep Freeze 64.

## INTRODUCTION

Large areas of the Polar regions are perpetually covered with snow. Since common building materials are not readily available, it is only natural that men should make use of snow in construction of polar camps. The military forces have developed methods for constructing tunnel enclosures to give protection from the elements. However, since snow and ice undergo plastic flow, provision must be made for periodic re-establishment of required dimensions in these enclosures.

This report is directed toward the determination of a positive method for trimming snow tunnel walls and for disposing of the snow. It is specifically concerned with the problem of tunnel closure being experienced at the New Byrd Station, Antarctica. Due to lack of precise information from that area, some of the study is based on information from Camp Century, a similar station in the Greenland Ice Cap.

## BACKGROUND

Under continuous loading, snow deforms or 'creeps' at a rate which is dependent primarily on the environment temperature and on the magnitude of the applied forces. When an opening, such as a tunnel, is made in snow, natural forces start at once to close it.

In the Greenland Ice Cap, tunnels were constructed near Tuto and at Camp Century which gave an opportunity for accurate measurement of the rates of closure under a rather wide range of conditions. Near camp Tuto two tunnels were excavated in the edge of the Ice Cap<sup>1</sup> at depths of 33 to 200 feet from the glacier surface. In contrast, Camp Century tunnels were constructed by a cut-and-cover method with a maximum tunnel floor depth of 62 feet.<sup>2</sup>

From the measurements of the closure rates at the Camp Tuto tunnels empirical equations were derived to predict maximum closure rates, as follows:<sup>1</sup>

$$\text{horizontal closure rate (ft/yr)} = \sqrt{\text{span}} (4.42 \times 10^{-4} H + 8.78 \times 10^{-8} H^3)$$

$$\text{vertical closure rate (ft/yr)} = \sqrt{\text{span}} (8.77 \times 10^{-4} H + 6.56 \times 10^{-8} H^3)$$

where H is depth of overburden in feet and span is in feet. These equations were restricted to the following:

1. Overburden depths of 30 to 200 feet
2. Tunnel temperatures from 15 to 25 F
3. Unsupported spans of 5 to 38 feet
4. Glacial ice

These equations do not seem to apply to some snow tunnels. According to them, a 25-foot-wide tunnel with a depth of 31 feet would have a vertical closure rate of about 0.2 in/yr. However, at Camp Century,<sup>2</sup> a tunnel with these dimensions and having a temperature range of 15 to 22 F was found to have a vertical closure rate of more than 2 ft/yr. It is probable that this rapid closure can be attributed to the relatively high temperatures maintained in some of the tunnels.

Though the tunnels at Byrd Station differ from those in Greenland, observations make it quite apparent that there will be a closure problem. A CRREL observer, Mr. M. Mellor, at Byrd Station during Deep Freeze 63 reported that the closure rates were moderate except where tunnel temperatures were permitted to exceed acceptable maximums. It was his opinion that snow removal would not be required during Deep Freeze 64 if these temperatures were controlled properly. A greater than average closure rate was observed in tunnel L-5 due to higher temperatures in that area, but more rigid adherence to known methods of controlling escape of heat from the buildings should remedy this situation. It was also reported that the roof had settled in a section of tunnel L-9 where the metal arches were removed. CRREL plans to publish a report including information on the tunnel closure rates at Byrd Station in the summer of 1963. This report and observations during the summer of Deep Freeze 64 should allow accurate prediction of the time when removal will be required.

#### REQUIREMENTS

There are about 3600 feet of tunnel at the New Byrd Station; 1600 feet with walls 12 feet high and 2000 feet with walls 20 feet high. For an inch of lateral closure on each side, the approximate quantity of snow to be removed would be:  $2 \times 3600 \times 16 \times 1/12 \times 1/27 = 355$  cu. yds. A closure of 6 to 12 inches might be tolerated in most sections before the restriction would cause undue inconvenience or hardship. With a 12-inch closure there would be need for removal of more than 4000 cubic yards of snow.

For an accumulation of 1000 cubic yards of snow per year equipment should be provided to permit removal of 1-1/2 to 2 cubic yards per

hour or, allowing for rest periods, approximately 10 cubic yards or 5 tons per 8 hour day. Light easily maneuverable machines should be provided such that two men may keep the tunnel walls trimmed to required dimensions. A schedule should be worked out whereby all sections of tunnel are brought to the proper configuration at specified intervals and not allowed to close to less than prescribed minimums. Observations to date indicate that wall trimming will be required at 2 to 4 year intervals.

Three basic concepts have been considered for clearing the tunnel walls at Byrd:

1. Use of men with only the most rudimentary tools such as picks, shovels, wheel barrows, ropes and buckets. Given enough men with these simple hand tools, together with ladders and scaffolding, it would be possible to trim or scale snow from the tunnel walls and convey it outside. This would be the cheapest method if manual labor were available at very low cost.

2. It would be possible, on the other hand, to design and build almost completely automatic machinery and operate it with skilled technicians to maintain tunnel dimensions. However, the costs involved in the design and construction of such special machines is very high.

3. Between these extremes one may establish a method whereby a few semi-skilled laborers can clear the tunnels with simple power tools, modified from those used for similar tasks in mining, earth moving and materials handling.

Figure 1 illustrates why the latter method probably gives the most economical solution under the existing situation. The curves in this figure were determined by the relationship:

$$C_t = \frac{C_e}{T_y} + C_o$$

Where  $C_t$  = Cost per ton

$C_e$  = Annual cost of equipment

$T_y$  = Number of tons cleared annually

$C_o$  = Operating cost per ton (labor, power etc.)

## CRITERIA

In dealing with the similar problem at Camp Century, the Army Engineers used and modified existing equipment, and designed new equipment to meet the needs of the situation.<sup>5</sup> Manual clearing with hand tools that used no power were too slow and could not be considered adequate under normal conditions. Hand held power tools weighing 40 pounds or more were unsatisfactory because of operator fatigue. Adequate time and personnel were not available to improve performance of the devices, modify the designs and adapt them to the particular situation. The use of more completely automatic machines was discouraged due to design and development costs, and to the need for highly skilled technicians to keep them in operating condition. Mechanical conveyors to transport the snow horizontally were tried and found to operate satisfactorily. A crusher was needed when snow was dislodged from the walls or ceiling in blocks. Materials blowers were found satisfactory for discharging the snow from the tunnel to the outside. Snow melting with electric energy was discarded, primarily because of its extremely inefficient use of fuel.

Consideration was given to the experience at Camp Century and to the physical make-up of the Byrd tunnels and structures in establishing the following general criteria for designing snow removal equipment at the New Byrd Station:

1. Air transport of the equipment.
2. Simplicity of design.
3. Simplicity and ease of assembly and of operation.
4. Minimum maintenance requirements.
5. Use of standard mechanisms and parts.
6. Minimum of congestion in the tunnels during clearing.
7. Maintenance of usual tunnel temperature during clearing.
8. Semi-automatic machines for clearing unobstructed passages.
9. Light, portable, hand-held power tools for restricted areas.
10. Sizes and shapes of equipment that allow ease of relocation within the tunnels.

11. Use of semi-skilled labor.
13. Normal safety devices on power driven equipment.
14. Freedom from contamination of air by smoke and carbon monoxide.

#### METHODS

About 75 percent of the tunnel wall surfaces at Byrd Station (tunnels M-1 part of L-3 and much of L-9) are free of obstructions to an extent that will allow a relatively high degree of mechanization of the trimming operations. The remaining 25 percent of tunnel length (tunnels L-2, L-4, L-5, L-7 and L-8) contain buildings and other obstructions that make the use of highly mechanized equipment impractical. Electric-driven, hand-held, tools should be used for these areas. Tunnel L-2, which is devoted largely to storage, has cabinets and shelving against the walls which preclude the use of the semi-automatic machines. Only a small section of roof or ceiling requires clearing. The metal roof arches were removed from tunnel L-9 in the vicinity of the geomagnetic and magnetic variations laboratory buildings to facilitate the use of special instrumentation. Overhead clearing will be required there at an early date. But since a comparatively small area is involved, the use of hand-held tools is justified.

On the basis of work done at Camp Century<sup>5</sup> the work requires three devices or mechanisms:

1. A trimmer to dislodge the excess snow from the walls.
2. A horizontal conveying mechanism to transport the snow to selected collecting stations.
3. A device to discharge the snow from the tunnel.

#### Wall Trimming Equipment

For clearing the unobstructed sections of the tunnels a modified digging machine with suitable characteristics should be used to dislodge the desired thickness of snow from the wall and discharge it to a horizontal conveyor. Since side walls rather than ceilings are the primary concern, this machine will differ from the one designed for Camp Century. It should have a toothed chain mechanism similar to that of a commercial ditch digger. Readily movable scaffolding and guiding tracks will be required to support and guide this machine along the walls.

Hand-held, electric-driven tools should be used for those tunnel sections which do not permit operation of the above machine. An

electric chain saw with a depth gage stop will cut blocks of size that can be handled readily. With it, the wall can be scored vertically and horizontally to the depth that is to be removed and a chipping hammer with an axe blade can be used to dislodge the blocks and smooth the surface. Ordinary shovels and wheel barrows will be needed for cleaning confined spaces. A block crusher can be used to reduce lumps to sizes and shapes that can be conveyed easily.

#### Snow Handling Equipment

An open, screw or flight type conveyor should be used to transport the loosened and crushed material horizontally to selected stations for discharge outside the tunnels. This conveyor can be of standard type probably aluminum alloy for lightness, with electric motor. It should have a minimum capacity of about 3 tons per hour. The conveyor should be made in sections of size that can be moved from place to place in the tunnels without undue difficulty. It should be possible to load snow into the conveyor anywhere along its length and the discharge should be at a height compatible with the inlet to the blower which elevates the snow to the surface outside the tunnel.

Discharge of the snow to the outside can be accomplished with a materials blower of size and type that can be moved easily to suitable discharge ports. This unit can be driven by an electric motor and its capacity should exceed the flow from the horizontal conveyor by an amount sufficient to avoid plugging under all normal circumstances.

#### Disposal of Snow

Use of electrical energy for converting the waste snow to water as it is scaled from the tunnels is not a practical process in the disposal of this material because of the excessive expenditure of fuel. A good diesel generator produces 1 kw hr for about 0.7 lb or 0.1 gal of fuel. Thus, about a ton of snow could be melted with 10 gallons of fuel. Efficient, direct heat snow melters use only about 2.5 gallons of fuel per ton.

In case the snow from the tunnel walls is clean and of satisfactory purity, it may be used to supplement the regular supply of snow for the water system. As the waste snow is discharged from the blower at the surface, it may be transported to the conveyor which discharges to the camp snow melter.

Disposal by dumping the waste snow on the surface and, if necessary, spreading to prevent drift formation can be used if an economical method for melting is not feasible.

## FINDINGS

The wall clearing study for New Byrd Station shows that:

1. Wall trimming will be required by Deep Freeze 65 in order to maintain the tunnel dimensions and clearances. Some areas may require clearing at one or two year intervals while others may go as long as four years before closure becomes objectionable.
2. For the most economical use of manpower and equipment the wall trimming should be accomplished by reasonably strict adherence to a predetermined schedule developed according to need.
3. Two types of wall trimming equipment will be required: mechanical devices for walls in the unobstructed tunnels and power-driven, hand-held tools for walls in tunnels containing buildings and other obstructions.
4. Conveyors and blowers will be needed for transport and removal of the snow from the tunnels.
5. Disposal and possible spreading of the waste snow on the surface near the tunnels may be necessary if an economical method for disposal by melting is not feasible.

## CONCLUSIONS

1. Rates of closure, and the maximum allowable safe closure in the various tunnels at New Byrd Station should be established at an early date in order to:
  - a. Develop a wall trimming schedule that will preclude damage to structures and equipment in the tunnels.
  - b. Prevent closures in restricted areas that will unduly hamper clearing.
2. Specific techniques and equipment should be determined for each different tunnel situation during Deep Freeze 64 toward a state of readiness for tunnel wall clearing by Deep Freeze 65.
3. Equipment for trimming the tunnel walls and disposing of the waste snow should be selected on a basis of removing the snow at a minimum cost and with the least inconvenience to normal station operations.

4. Based on this study it appears that commercially available equipment with some modifications can be adapted to all the work required for maintaining the tunnel wall clearances.

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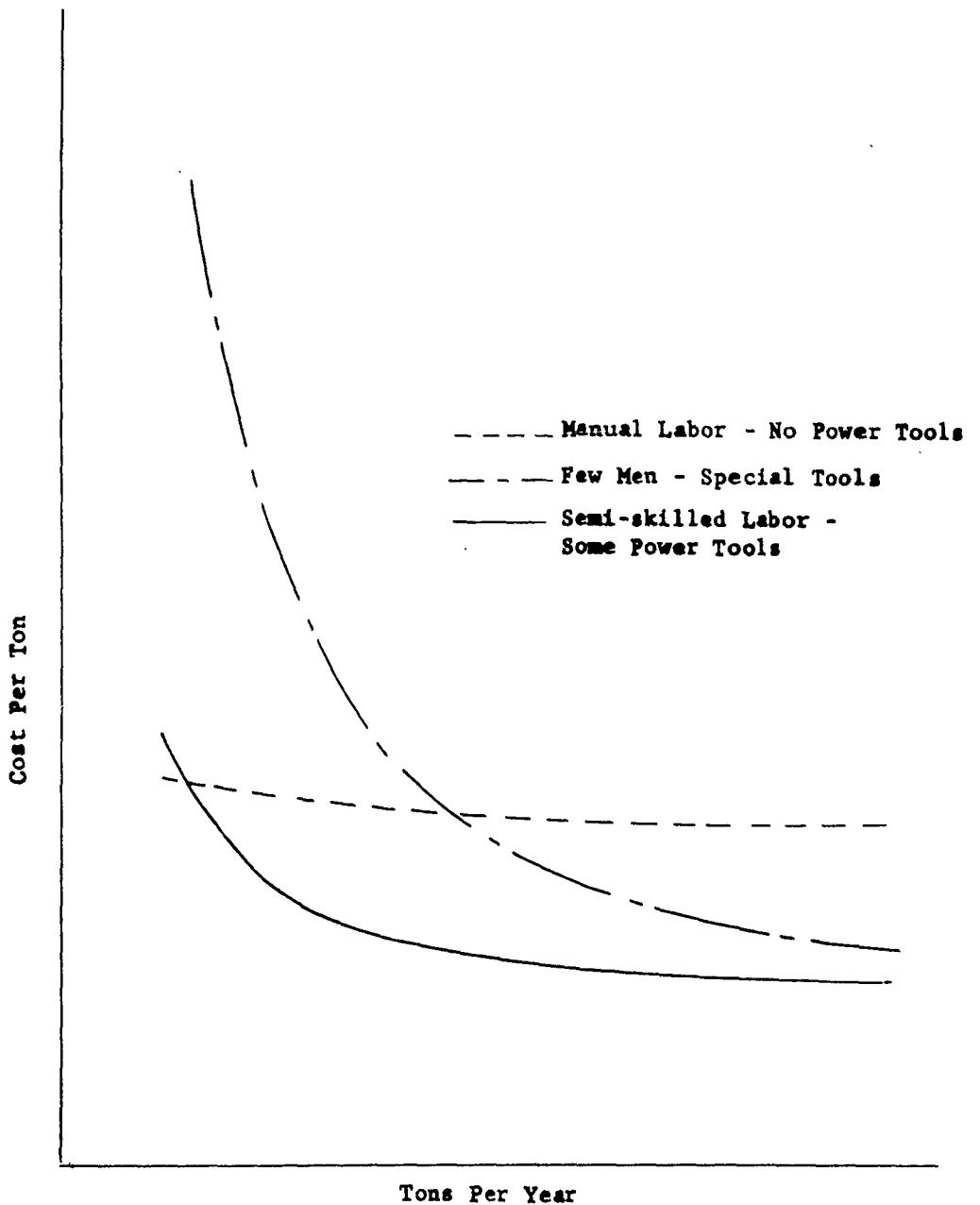


Figure 1. Curves Indicating Variation in Costs of Different Methods of Tunnel Clearing versus Quantity of Snow removed.